United States General Accounting Office

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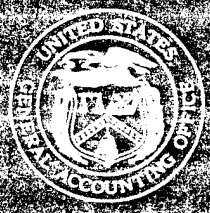
Report to the Chairman, Legislation and National Security Subcommittee, Committee on Government Operations, House of Representatives

July 1992

NASA

Changes to the Scope, Schedule, and Estimated Cost of the Earth Observing System



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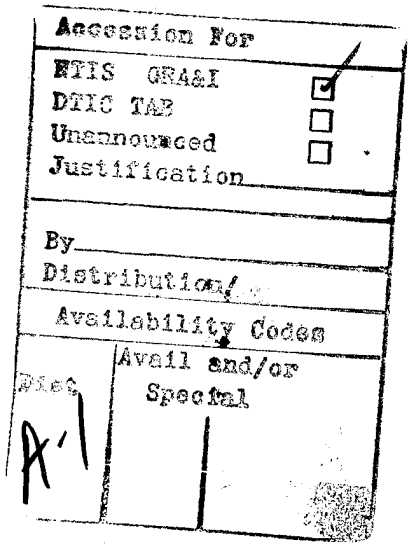


Jul 92

National Security and
International Affairs Division

B-248634

July 22, 1992

The Honorable Barbara Boxer
Chair, Government Activities and
Transportation Subcommittee
Committee on Government Operations
House of Representatives

Dear Madam Chair:

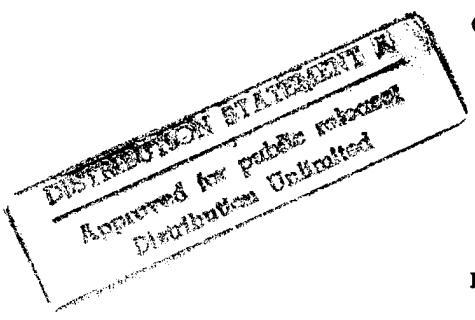
As you requested, we reviewed the status of the Earth Observing System (EOS). This program is the principal contribution of the National Aeronautics and Space Administration (NASA) to the government's study of climate and other global changes. This report describes EOS and the major changes made to its scope, schedule, and estimated cost due to its recent restructuring.

Background

NASA: Changes to the Scope, Schedule, and Estimated Cost of the Earth Observing System

Congress funded EOS as a new NASA program beginning in fiscal year 1991. NASA proposed to launch about 30 types of earth observing instruments beginning in 1998. These instruments were intended to improve satellite data about the earth and to provide new data to support interdisciplinary studies of the earth.

EOS is seen by NASA as the first step toward a future period of space-based scientific observation of the earth. The program is directly linked to the objectives of the U.S. Global Change Research Program and international efforts to observe and study the earth. The U.S. Global Change Research Program, which is funded by 11 agencies, is an attempt to achieve these objectives and to improve predictions of climate and other forms of global change. Within that program, EOS is intended to significantly improve scientists' abilities to model, and thereby predict, broad natural relationships among the sea, land, and atmosphere; to observe how water, carbon, and other substances move on the planet or are affected by variations in the sun's radiation; and to assess the impact of human activities on the earth's climate. Ultimately, EOS is to help determine the extent to which human activities are affecting the earth's environment and to provide policymakers the information they will need to preserve the earth.



Results in Brief

Primarily as a result of congressional direction, NASA, after an extensive review of EOS during the fall of 1991, restructured the program and changed its content, schedule, and estimated cost for most of its activities through fiscal year 2000.

The EOS restructuring focused the program on climatic change and deleted scientific objectives and instruments related to upper atmosphere studies and measurements of solid earth processes. This reduction in scope was accompanied by a change to a greater number of smaller satellites to be launched on a schedule that delays the start of operations for most instruments in the restructured program by a little over 2 years. Overall, the program changes reduced NASA's estimate for most of its funding requirements through fiscal year 2000 from about $16 billion to $11 billion.

There is a potential for an adverse impact on the remaining scientific objectives of the restructured EOS program. Specifically, fully achieving the program's climatic change objectives partly depends on NASA's ability to arrange development and flight opportunities for some planned instruments that are now partly or totally outside the program's funding profile through fiscal year 2000. Unless NASA is successful, science related to radiation balance data and wind speed and direction in the lower atmosphere may be adversely affected. NASA needs to periodically apprise the Congress of its progress in establishing satisfactory arrangements so that the Congress can determine whether and to what extent it wants to continue supporting these instruments.

Reconfiguration Changed EOS Program Content, Schedule, and Cost

As a result of the recent reconfiguration of the EOS program, science related to upper atmospheric studies and measurements of solid earth processes was deleted. Essentially, the restructured program has been focused on global climatic change. To gather data on climatic change, the program will now use six different types of medium to small satellites. Previously, NASA had planned to use one type of large satellite, followed by either a second type of large satellite or a mix of smaller satellites. Under the new configuration, EOS is estimated to cost $11 billion through fiscal year 2000, down from an estimate of about $16 billion for the previous program configuration.

Under the restructured program, NASA has scheduled the launch of its first EOS satellite 6 months earlier in 1998 than previously planned. However, it will be more limited in application, and overall, the planned start of

operations for most EOS instruments has been delayed for 1 to over 4 years, with an average delay of a little over 2 years. More detailed information about the scope and purpose of the EOS program and changes to its content, schedule, and estimated cost is in appendix I. The instruments planned for the reconfigured EOS platforms are described in appendix II.

Status of Some EOS Instruments Under the Reconfigured Program Is Uncertain

Maintaining the scientific objectives that are planned under the restructured EOS program is partly dependent on NASA's success in identifying domestic or international partners for some EOS instruments. Specifically, NASA needs to arrange for the development and flight of a technically challenging instrument—the Laser Atmospheric Wind Sounder (LAWS)—the only instrument for making direct observations of lower atmospheric winds. NASA also needs to arrange flight opportunities for other instruments it plans to develop but that are not yet assigned to a satellite, including the only two instruments designed to measure solar input to the atmosphere. NASA personnel working to arrange development and flight opportunities have not been successful so far. Unless NASA's efforts are successful, there is a potential for an adverse impact on the scientific objectives related to radiation balance data and measurements of wind direction and speed in the lower atmosphere. More information on planned instruments that have not yet been assigned to a satellite and instruments that have been deferred or canceled is in appendix III.

Recommendation

We recommend that the NASA Administrator periodically inform the Congress about the status of the agency's efforts to arrange development and/or flight support for planned instruments that are needed to help achieve EOS scientific objectives but are outside the program's funding profile through fiscal year 2000.

Scope and Methodology

We reviewed documents that described domestic and international global change research efforts. In addition, we reviewed the results of the external engineering committee's work on the EOS program, NASA's response to that review, and documents related to the reconfiguration of the EOS satellite system. We also attended NASA's science review of the program and a review of small satellite technology sponsored by the Committee on Earth and Environmental Sciences.

We performed our work at NASA Headquarters, Washington, D.C., and at Goddard Space Flight Center, Greenbelt, Maryland. We had discussions with program officials from NASA's Office of Space Science and Applications and the Goddard Space Flight Center and with representatives of the U.S. Global Change Research Program and its Committee on Earth and Environmental Sciences.

We conducted our review from September 1991 to June 1992 in accordance with generally accepted government auditing standards. As requested, we did not obtain NASA's comments on this report. We discussed the results of our work with NASA officials and incorporated their comments where appropriate.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after its issue date. At that time, we will send copies to the NASA Administrator and other interested congressional committees. We also plan to make copies available to others upon request.

If you have any questions, please call me on (202) 275-5140. Major contributors to this report are listed in appendix IV.

Sincerely yours,

Mark E. Gebicke

Mark E. Gebicke
Director, NASA Issues

Contents

Figures

Abbreviations

ACRIM	Active Cavity Radiometer Irradiance Monitor
AIRS	Atmospheric Infrared Sounder
ALT	Altimeter
AMSU-A	Advanced Microwave Sounding Unit-A
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CERES	Clouds and Earth's Radiant Energy System
EOS	Earth Observing System
EOSP	Earth Observing Scanning Polarimeter
GGI	Global Positioning System Geoscience Instrument
GLRS-A	Geoscience Laser Ranging System-Altimeter
GLRS-R	Geoscience Laser Ranging System-Ranger
GOS	Geomagnetic Observing System
GPS	Global Positioning System
HIRDLS	High-Resolution Dynamics Limb Sounder
HIRIS	High-Resolution Imaging Spectrometer
IPEI	Ionospheric Plasma and Electrodynamic Instrument
LAWS	Laser Atmospheric Wind Sounder
LIS	Lightning Imaging Sensor
MHS	Microwave Humidity Sounder
MIMR	Multifrequency Imaging Microwave Radiometer
MISR	Multi-Angle Imaging Spectro-Radiometer
MLS	Microwave Limb Sounder
MODIS-N	Moderate-Resolution Imaging Spectrometer-Nadir
MODIS-T	Moderate-Resolution Imaging Spectrometer-Tilt
MOPITT	Measurements of Pollution in the Troposphere
NASA	National Aeronautics and Space Administration
NSCAT	NASA Scatterometer
POEM	Polar-Orbit Earth Observation Mission
SAFIRE	Spectroscopy of the Atmosphere Using Far Infrared Emission
SAGE	Stratospheric Aerosol and Gas Experiment
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
STIKSCAT	Stick Scatterometer
SWIRLS	Stratospheric Wind Infrared Sounder
TES	Tropospheric Emission Spectrometer
TRMM	Tropical Rainfall Measuring Mission
UARS	Upper Atmosphere Research Satellite
XIE	X-Ray Imaging Experiment

Changes to the Earth Observing System's Content, Schedule, and Cost

The National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) program is a component of a broader research effort by U.S. agencies, in cooperation with international scientific organizations, to study the earth and to address key uncertainties about its condition and its changes. Primarily as a result of congressional direction, NASA recently completed a reevaluation, reconfiguration, and rephasing of the EOS program. Major adjustments included a change to smaller satellites for all EOS missions, the deferral or deletion of some instruments, a delay in the planned start of operations for most of the instruments still in the program for an average of over 2 years each, and a reduction of over 30 percent, or almost $5 billion, in the estimated contract cost for developing and operating EOS through fiscal year 2000.

Scientific Uncertainties Limit Ability to Predict Climatic Changes

In 1990, the Intergovernmental Panel on Climate Change[1] noted that basic knowledge gaps in several key areas resulted in the general uncertainty about the state of the earth. Specifically, the ability to predict whether and how climatic changes occur is limited by a lack of data on

- effects of cloud formation and dissipation on incoming and outgoing radiation,
- ocean and atmosphere energy exchange,
- sources and points of accumulation of greenhouse gases[2] and the pattern and rate of chemical change in the atmosphere,
- effect of polar ice formation and melt on the sea level, and
- interaction of water and biology together and with the environment over land surfaces.

Lack of data in these areas impedes the development of general circulation prediction models of the earth's climate that are needed for scientific study and policy assessment.

The U.S. Global Change Research Program has set out a plan of multiagency research and earth observations, both space- and ground-based. NASA is the lead agency for the space-based portion of the program. Each year, the Committee on Earth and Environmental Sciences, an advisory body to the Office of Science and Technology Policy and the

[1]This panel is an international scientific body organized under the auspices of the United Nations Environment Programme and the World Meteorological Organization.

[2]Greenhouse gases, such as carbon dioxide and methane, are thought to contribute to warming of the earth's climate.

cabinet secretaries, evaluates and develops the program's major components and their recommended funding levels. U.S. agencies providing funding for the program, in order of highest to lowest amounts requested for fiscal year 1993, are shown in table I.1.

Table I.1: U.S. Global Change Research Program Fiscal Year 1993 Budget Request

Dollars in millions

Agency	Amount
National Aeronautics and Space Administration	$890.8
National Science Foundation	162.5
Department of Energy	113.0
Department of Commerce	78.2
Department of Agriculture	47.6
Department of the Interior	35.8
Environmental Protection Agency	26.0
Smithsonian Institution	10.6
Department of Defense	6.6
Department of Health and Human Services	1.2
Tennessee Valley Authority	0.1
Total	**$1,372.4**

The U.S. program sponsors work in seven areas of scientific investigation: earth climate and hydrology, interaction of earth biology and chemistry, earth ecology, history of the earth, role of human society, solid earth processes, and role of the sun in influencing earth processes. The program involves a combination of space-based observations and ground-based research.

The work in these scientific areas under the U.S. program has been integrated into four "themes": methods of climate modeling, water and energy cycles, the global carbon cycle, and the manner in which ecological systems and individual plant and animal species respond to climatic change. Some of these themes also involve studying how human society interacts with the earth's natural processes.

EOS Planned As a Multipurpose, High Quality Observation System

Conceived in the early 1980s, EOS is the principal space-based component of the U.S. Global Change Research Program.[3] It is composed of four major elements: the spacecraft, the instruments to be flown, a combined satellite control and science data management system, and the development and operation of science projects. EOS is to provide at least 15 years of continuous, high quality data about the earth in support of research in earth system science, which integrates such scientific disciplines as atmospheric science, oceanography, biology, and geology. EOS and other global change research activities are intended to advance the state of understanding of the earth to enable scientists to predict how it is changing and to provide policymakers with the information they need to plan for the future.

EOS Reconfiguration and Schedule Changes

Up until mid-1991, NASA planned to begin its EOS program by launching 15 instruments in 1998 on a single, large satellite (EOS-A1). Another 14 instruments were to be launched around the year 2001 on either another large satellite or multiple medium- to small-size satellites[4] (EOS-B1). Similarly instrumented satellites (EOS-A2 and A3; EOS-B2 and B3) were to be launched at 2-1/2-year intervals. As each satellite was to have a 5-year life, each series would have provided 15 years of coverage.

Because funding through fiscal year 2000 was limited to $11 billion by the Congress, the scope and timing of the program as originally planned could no longer be accomplished. In addition, in the spring of 1991, NASA, with input from the National Space Council, the Office of Management and Budget, and the Office of Science and Technology Policy, formed an external engineering review committee to advise the agency on the planning for EOS and on whether EOS scientific objectives could be met using an alternative configuration of satellite systems. The committee

[3]Other NASA satellites and instruments that also are intended to contribute to the U.S. Global Change Research Program include the currently operating Upper Atmosphere Research Satellite (UARS) and the planned Tropical Rainfall Measuring Mission (TRMM). NASA projects like these, plus missions of other U.S. and foreign agencies, are complementary to EOS, and the data they collect are to be available through the EOS program. Taken together, these missions and programs constitute the "Mission to Planet Earth."

[4]At one point, NASA had intended to use a large platform for the EOS-B series, which would probably have been a standardized satellite based on the EOS-A platform. However, a NASA study dated May 1990 determined that it was financially and technically feasible to break up the EOS-B platforms into smaller satellites. A final decision about the size of the EOS-B platforms had not been made before the Congress directed that the program be changed.

concluded that EOS science objectives could be met using small to medium-size systems.[5]

After extensive review of EOS during the fall of 1991, NASA reconfigured the program to maintain a 1998 initial launch date, downsized to medium and small platforms, deleted or deferred some instruments from the program, and delayed the development and launch of most of the remaining EOS instruments for 1 to over 4 years, with an average delay of a little over 2 years. Table I.2 shows the launch schedule of the EOS platforms before and after the reconfiguration.

Table I.2: Launch Schedule Before and After Reconfiguration

Year	Before	After
1998	A1	Morning-1/Ocean Color
1999		
2000		Aerosol-1/Afternoon-1
2001	B1	
2002		Altimeter-1/Chemistry-1
2003	A2	Morning-2/Aerosol-2
2004		
2005		Afternoon-2
2006	B2	Aerosol-3
2007		Altimeter-2/Chemistry-2
2008	A3	Morning-3
2009		Aerosol-4
2010		Afternoon-3
2011	B3	
2012		Altimeter-3/Chemistry-3/ Aerosol-5

The primary areas to be studied by the reconfigured platforms are listed in table I.3.

[5]The review committee also assessed how global climate change could be monitored from space prior to the planned EOS initial launch date of 1998. The committee's other recommendations focused on how the Department of Energy and the Department of Defense could support NASA and the U.S. Global Change Research Program, including the possibility of performing earth radiation balance measurements earlier than 1998 using technologies available from those agencies.

Table I.3: Science Missions of Reconfigured EOS Platforms

Platform	Primary area of study
Morning	Land cover, clouds, aerosols,[a] and radiation balance
Ocean Color	Ocean biomass and productivity
Aerosol	Tropospheric and stratospheric aerosols
Afternoon	Clouds, precipitation and radiation balance, terrestrial snow and sea ice, sea-surface temperature, and ocean productivity
Altimeter	Ocean circulation and ice sheet mass balance
Chemistry	Tropospheric and lower stratospheric chemistry and surface winds

[a]An aerosol is a suspension of fine solid or liquid particles in gas.

Table I.4 lists the EOS instruments and their assigned platform(s) before and after the reconfiguration. The name of each instrument and a brief description of each are given in appendixes II and III. The instruments may change as more scientific data become available and development challenges become better known.

Table I.4: EOS Instruments Before and After Reconfiguration

Instruments	Before	After
ACRIM-III	A series	Instrument funded; no platform assigned
AIRS	A series	Afternoon series[a]
ALT	B series	Altimeter series
AMSU-A	A series	Afternoon series
ASTER	A1	Morning-1
CERES	A series; TRMM; POEM-1[b]	Morning and Afternoon series; TRMM[b]
EOSP	A series	Morning-2; mission of opportunity[c]
GGI	B series	Altimeter series
GLRS	B series	GLRS-A on Altimeter series; GLRS-R canceled
GOS	B series	Canceled
HIRDLS	A series; B series	Chemistry series; may fly earlier on an international platform
HIRIS	A2; A3	Morning-2; may also fly on Morning-3
IPEI	B series	Canceled
LAWS	B series	Funding for development and flight deferred
LIS	A series; TRMM[b]	TRMM[b]
MHS	A series	Afternoon series[a]
MIMR	A series	Afternoon series
MISR	A series	Morning series
MLS	B series	Less capable MLS or SAFIRE funded; no platform assigned
MODIS-N	A series	Morning and Afternoon series
MODIS-T	A series	Canceled
MOPITT	A1	Morning-1
SAFIRE	B series	Less capable SAFIRE or MLS funded; no platform assigned
SAGE-III[d]	B series	Aerosol series; Chemistry series
SeaWiFS-II[e]	Not in program	Ocean color
SOLSTICE	B series	Instrument funded; no platform assigned
STIKSCAT[f]	A series	Chemistry series
SWIRLS	B series	Canceled
TES	B series	Chemistry series
XIE	B series	Canceled

[a]AIRS may become an operational instrument for the National Oceanic and Atmospheric Administration. If so, the AIRS instruments currently planned for Afternoon-2 and -3 may be flown on the Administration's satellites instead. In either case, MHS will be coupled with AIRS.

[b]TRMM, to be flown in 1997, is part of NASA's Earth Probes program. The EOS program will fund the flight of CERES and LIS on that mission. In addition, a CERES instrument funded by the EOS program had been scheduled to fly on Europe's Polar-Orbit Earth Observation Mission-1 (POEM-1) platform prior to the restructuring.

[c]The decision to fly EOSP on Morning-2, and possibly on Morning-3, is pending a science review. Even if the instrument flies on one or both of these platforms, it will still be considered for placement on other satellites as a mission of opportunity.

(continued)

[d]SAGE-II, an earlier version of SAGE-III, may fly on Europe's POEM-1 platform. If it does, the instrument will be funded under the EOS program.

[e]The instrument for the Ocean Color platform may be SeaWiFS-II or another similar instrument.

[f]NSCAT, an earlier version of STIKSCAT, may fly on the Japanese Advanced Earth Observing Satellite-II platform. If it does, the instrument will be funded under the EOS program.

The general launch schedule for 1998 to 2002 for EOS platforms before and after reconfiguration, with their planned instrumentation, is shown in table I.5.

Table I.5: General EOS Platform Launch Schedule Before and After Reconfiguration With Planned Instrumentation, 1998-2002

	Before		After	
Year	**Platform**	**Instruments(number)**	**Platform**	**Instruments(number)**
1998	A1	ACRIM-III, AIRS, AMSU-A, ASTER, CERES, EOSP, LIS, HIRDLS, MHS, MIMR, MISR, MODIS-N, MODIS-T, MOPITT, STIKSCAT (15)	Morning-1 Ocean Color	ASTER, CERES, MISR, MODIS-N, MOPITT (5) SeaWiFS-II or other similar instrument (1)
1999	None		None	
2000	None		Aerosol-1	SAGE-III (1)
			Afternoon-1	AIRS, AMSU-A, CERES, MHS, MIMR, MODIS-N (6)
2001	B1	ALT, GGI, GLRS, GOS, HIRDLS, TES, IPEI, LAWS, MLS, SAFIRE, SAGE-III, SOLSTICE, SWIRLS, XIE (14)	None	
2002	None		Altimeter-1	ALT, GGI, GLRS-A (3)
			Chemistry-1	HIRDLS, SAGE-III, STIKSCAT, TES (4)

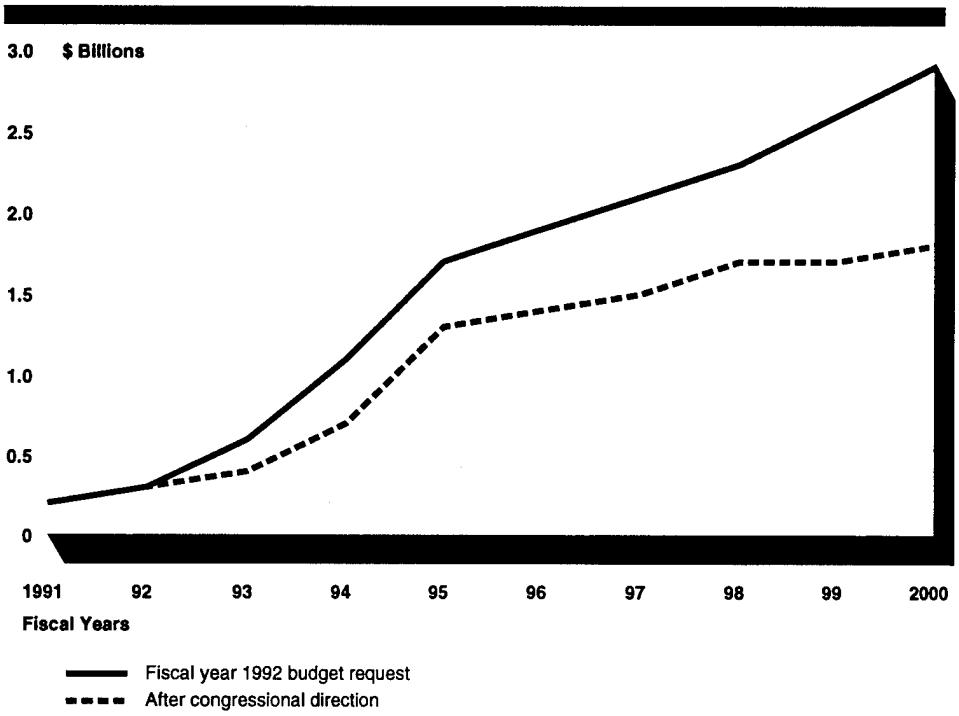
Note: The abbreviations are identified in appendixes II and III.

NASA's EOS Funding Estimates Through Fiscal Year 2000 Have Been Significantly Reduced

Since program reconfiguration, the cost of the EOS program through fiscal year 2000 has been reduced from about $16 billion to $11 billion.[6] Figure I.1 shows NASA's EOS funding estimates annually through fiscal year 2000 before and after the program was restructured.

[6]NASA's cost estimates cover contract funding requirements for developing and operating EOS through 2000. They do not include the estimated costs of special EOS facilities, NASA personnel, or other NASA programs supporting EOS launch and operations.

Figure I.1: Estimates of EOS Annual Funding Requirements Through Fiscal Year 2000 Before and After Reconfiguration



Fiscal year 1992 funding projections for fiscal years 1998 through 2000 total $7.9 billion. The yearly amounts were not available. For this illustration, GAO distributed the total to each year, assuming a $200 million to $300 million annual increase.

GAO analysis based on NASA data.

The overall funding profile shows a slight divergence starting in fiscal year 1992 that grows slowly until, by fiscal year 1995, the annual difference is over $400 million, with an aggregate difference through that year of about $1.2 billion. Most of the cost reduction occurs in the last 5 years of the estimate. The distribution of the 31 percent reduction in the EOS cost estimate through fiscal year 2000 among selected program activities is shown in table I.6.

Table I.6: Cost Estimates Through Fiscal Year 2000 for Selected EOS Program Activities Before and After Reconfiguration

Dollars in millions

Activity	Before	After	Reduction	
			Amount	Percent
Instruments, platforms, and science	$10,811	$8,348	$2,463	23
Information system	3,900	2,141	1,759	45
Mission operations	1,160	511	649	56
Total	**$15,871**	**$11,000**	**$4,871**	**31**

Source: GAO analysis based on NASA data.

A total cost estimate for the reconfigured EOS program has not yet been developed. EOS program officials told us that they plan to have a total estimate later this year. Although not well defined at this time, EOS funding requirements after fiscal year 2000 are likely to be considerable. As previously noted, the adjustments to program content and pace have included slipping the planned start of operations for many instruments for 1 to 4 years, with an average delay of a little over 2 years. These and other adjustments to the program portend significant costs after fiscal year 2000.

Instruments for Each Reconfigured EOS Platform

Morning:

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

Provides very high-resolution images of land, water, and cloud surfaces. The High-Resolution Imaging Spectrometer (HIRIS) will replace ASTER, a Japanese instrument, on at least one of the succeeding Morning platforms. The data provided by HIRIS will be similar to those of ASTER but will exclude coverage of the thermal infrared spectrum. Development risk is moderate to high.[1]

Clouds and Earth's Radiant Energy System (CERES)

Will measure the total radiation from the earth's surface to the top of the atmosphere. CERES is an upgrade of the Earth Radiation Budget Experiment. Development risk is low to moderate.

Earth Observing Scanning Polarimeter (EOSP)

Will provide general information about the optical properties of the earth's lower atmosphere and about atmospheric aerosols and clouds. Development risk is low to moderate.

High-Resolution Imaging Spectrometer (HIRIS)

Will provide high-resolution images of the earth's vegetation and soil characteristics, minerals, snow and ice cover, ocean color, and clouds and aerosols. Development risk is high.

Multi-Angle Imaging Spectro-Radiometer (MISR)

Will provide top-of-the-atmosphere cloud and surface reflectance data. Development risk is moderate.

Moderate-Resolution Imaging Spectrometer-Nadir (MODIS-N)

A general purpose instrument with applications in most categories of global change research. Data sets from two MODIS-N instruments and MISR

[1]The stated development risk of this and other instruments described in this appendix is based upon a November 21, 1991, NASA assessment.

can be merged to correct for sun glint. Development risk is moderate to high.

Measurements of Pollution in the Troposphere (MOPITT)

Will measure lower atmospheric carbon monoxide and methane concentrations. Development risk for this Canadian instrument is moderate to high.

Ocean Color:

Sea-Viewing Wide Field-of-View Sensor-II (SeaWiFS-II) or similar instrument

Will gather information about ocean color and marine biological productivity. NASA will purchase the data collected by this instrument until MODIS-N is launched on the Afternoon-1 platform.

Aerosol:

Stratospheric Aerosol and Gas Experiment-III (SAGE-III)

Will scan the earth's atmosphere for data on aerosols, water vapor, and several atmospheric gases to measure the ozone profile. SAGE-III will be based on earlier versions of the same instrument. Development risk is low to moderate.

Afternoon:

Atmospheric Infrared Sounder (AIRS)

Will provide high-resolution information about atmospheric humidity and temperature. Development risk is high.

Advanced Microwave Sounding Unit-A (AMSU-A)

Will provide atmospheric temperature measurements from the earth's surface to 40 kilometers. Development risk is moderate.

Clouds and Earth's Radiant Energy System (CERES)

Same as the Morning platform instrument. CERES will be flown here to obtain measurements at two different times of the day to determine diurnal variations in radiation.

Microwave Humidity Sounder (MHS)

Will provide atmospheric water vapor profile measurements. Development risk for this European Meteorological Satellites Organization instrument is moderate.

Multifrequency Imaging Microwave Radiometer (MIMR)

Will provide general information on moisture conditions of the earth. Development risk for this European Space Agency instrument is moderate to high.

Moderate-Resolution Imaging Spectrometer-Nadir (MODIS-N)

Same as the Morning platform instrument. MODIS-N will be flown here to obtain simultaneous observations with other Afternoon instruments and measurements at two different times of the day to determine diurnal variations.

Altimeter:

Altimeter (ALT)

Will facilitate mapping the changing topography of the sea and ice. This instrument is needed to maintain continuity with existing satellite altimetry data. Development risk is moderate.

Global Positioning System (GPS) Geoscience Instrument (GGI)

Will use GPS satellite data to accurately determine the position of the Altimeter platform. Development risk is low to moderate.

Geoscience Laser Ranging System-Altimeter (GLRS-A)

Will provide measurements of ice sheet height and surface condition. Development risk has not been assessed.

Chemistry:

High-Resolution Dynamics Limb Sounder (HIRDLS)

Will provide a wide range of data about the earth's upper atmospheric chemistry. Measurements from this joint U.S.-U.K. instrument will constitute a follow-on to some of the data currently being gathered by UARS. Development risk is moderate to high.

Stratospheric Aerosol and Gas Experiment-III (SAGE-III)

Same as the Aerosol platform instrument.

Stick Scatterometer (STIKSCAT)

Will measure surface wind speed and direction over the ocean. Development risk is moderate.

Tropospheric Emission Spectrometer (TES)

Will provide information on lower atmospheric chemistry. Development risk has not been assessed.

In addition to the instruments flying on the six types of EOS platforms, there are two EOS-funded instruments scheduled to fly on the TRMM in 1997. These are the CERES instrument (also flying on the Morning and Afternoon satellites) and the Lightning Imaging Sensor (LIS), which will investigate the distribution and variability of lightning, as well as its relationship to rainfall and to the global electric current.

Planned Instruments Without Current Flight Opportunity and Canceled and Deferred Instruments

Under the reconfigured EOS program, some previously planned instruments can no longer be funded. NASA considers one of these instruments as deferred until after fiscal year 2000 and is seeking domestic or international partners for its development and flight. Other instruments that NASA is planning to develop do not currently have assigned space on a satellite. Thus, NASA is trying to place these instruments on other domestic or international satellites.

If the deferred instrument is sponsored and the EOS-funded instruments are assigned to satellites, the science adversely affected by the program restructuring will have been limited principally to upper atmospheric studies and measurements of solid earth processes. If these instruments do not find development and flight opportunities, there will be further adverse effects on radiation balance data and measurements of wind speed and direction in the lower atmosphere.

Funded Instruments Not Assigned to Satellites

Table III.1 lists those instruments that NASA will continue developing under the EOS program but which do not have space on a satellite and for which NASA is currently seeking flight opportunities on the satellites of foreign space agencies—including the European Space Agency and the National Space Development Agency of Japan—or other U.S. agencies.

Table III.1: EOS Instruments Not Yet Assigned to a Platform

Active Cavity Radiometer Irradiance Monitor-III (ACRIM-III) Measures variations in the output of the sun. ACRIM-II is currently flying on UARS.
Solar Stellar Irradiance Comparison Experiment (SOLSTICE) Measures variations in the sun's output of ultraviolet radiation. A SOLSTICE instrument is currently flying on UARS.
Microwave Limb Sounder (MLS)[a] Measures upper atmospheric chemical processes, emphasizing the chemicals related to ozone depletion. An MLS is currently flying on UARS.
Spectroscopy of the Atmosphere Using Far Infrared Emission (SAFIRE)[a] Measures middle atmospheric chemical processes, including stratospheric ozone depletion. This multinational instrument is regarded as a general follow-on to UARS.

[a]NASA plans to place a less capable version of one of these two instruments on a domestic or international satellite.

Deferred and Canceled Instruments

Six EOS instruments have been canceled and one has been deferred until after fiscal year 2000. These instruments would have gathered data in the areas of solid earth science, ocean biomass, and upper atmospheric winds and particle physics (see table III.2).

Table III.2: Deferred and Canceled EOS Instruments

Laser Atmospheric Wind Sounder (LAWS)
A doppler light detection and ranging instrument, which will use a laser to measure wind speed and direction in the lower atmosphere. It is the only instrument designed to make direct observations of surface winds in the lower atmosphere.
Geoscience Laser Ranging System-Ranger (GLRS-R)
The laser ranging portion of the Geoscience Laser Ranging System used to study solid earth processes.
Moderate-Resolution Imaging Spectrometer-Tilt (MODIS-T)
An instrument designed specifically for studies of ocean biomass as a source of atmospheric gases.
Stratospheric Wind Infrared Limb Sounder (SWIRLS)
An instrument used to measure winds in the upper atmosphere.
X-Ray Imaging Experiment (XIE), Ionospheric Plasma and Electrodynamics Instrument (IPEI), and Geomagnetic Observing System (GOS)
Instruments for performing particle physics research of the upper atmosphere.

All instruments shown in table III.2 except LAWS were canceled. NASA considers LAWS deferred, and it would like to develop and fly it after fiscal year 2000. LAWS will be a technically challenging instrument to develop, and currently there is no funding for its development or flight. NASA is discussing possible collaboration on the instrument with the Departments of Defense and Energy and with the French.

In addition, instead of using MODIS-T to obtain ocean biomass data, NASA plans to purchase the ocean information gathered by the SeaWiFS-II or other similar instrument on the Ocean Color mission that was added to the reconfigured program. These data will be used in conjunction with ocean information to be provided by the multipurpose MODIS-N instrument flying on the Morning and Afternoon platforms.

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